DOCUMENT RESUME

ED 302 402 SE 050 236

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TITLE Girls and Technology: Stories of Tools and Power.
INSTITUTION Girls Clubs of America, Inc., Indianapolis, IN. National Resource Center.
PUB DATE 88
NOTE 11p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 5-9, 1988). For other papers about Operation SMART, see SE 050 234-238.
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Elementary Secondary Education; Equal Education; *Females; Museums; *Nonformal Education; *Role Models; Science Activities; *Science and Society; *Science Education; *Sex Differences; Teaching Methods; Technology; Youth Clubs
IDENTIFIERS Girls Clubs of America; *Operation SMART

ABSTRACT

Operation SMART (Science, Math and Relevant Technology) is a project of the Girls Clubs of America, a national organization serving mostly low-income girls in local club centers. Girls clubs provide out-of-school programming that pays special attention to the needs of girls and helps them take charge of their futures. Operation SMART's hands-on science activities and visits to role models in science are accompanied by reflection about science, societal issues, and personal attitudes. This document describes the goals and programs of this operation including the background of the project and the impact that can be made on the attitudes of girls regarding science and technology. Discussed in this paper are the demystification of science and mathematics, the importance of the actual manipulation of materials, the power of symbols, the importance of collaborative experiences, and the issue of self-reliance versus learned incompetence. (CW)

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GIRLS AND TECHNOLOGY: STORIES OF TOOLS AND POWER

Ellen Wahl, Director of Operation SMART

Presented at the American Educational Research Association
Symposium on "Women and Technology: New Perspectives on Design and Use"
April 8, 1988

ED302402

> Ten-year-old girls were out in the backyard of the Schenectady Girls Club fixing their bicycles in bike repair class. Three eleven-year-old boys walked by. "Hey, what are you doing?" challenged one of the boys. "That's not girls' work!" Wrench in hand, Deborah looked up and scowled: "It is so girls' work. Or are you going to be around every time I need to fix my bike? No way!"
>
> A group of boys at the coed Girls Club of Casper, Wyoming spent hours building a fort with lumber and nails in back of the building. I [the Club's director] encouraged it, and sent out whatever tools or materials they asked for. Then the weather turned nasty and I made them come in. When the sun came back out, two very small girls went out and kicked the fort down in less than two minutes. The boys came to me, full of righteous indignation, and demanded reparation. We have Club meeting once a day, so we put it to the members -- what should be done? The consensus, by a pretty resounding majority, was that it couldn't have been much of a fort in the first place. The big girls got interested, and said they could build a much better one in less time -- which they did, much to the disgust of the boys. The only thing that saved the backyard from filling up with competitive shacks was the arrival of a good Wyoming winter.

In the three years since Girls Clubs of America established Operation SMART,[1] its national program to encourage girls' and young women's participation in science, math, and technology, these scenes have been played out again and again. Given the opportunity to explore machines, use tools, take things apart, get their hands dirty and their minds engaged, girls transform technology from a male domain into one over which they can have control. "Technology" in Operation SMART is defined in the most basic way -- how human beings make and use tools to manipulate their environment.

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[1]Operation SMART is funded by the National Science Foundation, Carnegie Corporation of New York, The Ford Foundation, General Electric Foundation, Allied-Signal Corporation, Apple Computer, Inc., GTE Foundation, McDonald's, Metropolitan Life Foundation, The Amelia Peabody Foundation, Texaco Philanthropic Foundation, and Union Carbide Corp[illegible]ion. Findings and opinions are those of the author and do not necessarily reflect positions of the funders.

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Whether girls use screw drivers or computers, power drills or video equipment, maps or floor plans, they are learning a new way to relate to their physical world, and gaining a sense of confidence and competence about themselves that translates into power, independence, and action.

Girls Clubs of America is the umbrella organization for more than 200 local centers across the country. Building-based, professionally staffed organizations, Girls Clubs provide informal education and recreation after school and during the summer to a quarter of a million girls each year. More than two-thirds of members are from families with incomes under $15,000 per year, and close to half are members of minority groups. They comprise a population that has had limited access to opportunities in science and technology. Through Girls Clubs and Operation SMART, they are gaining the skills, experience, and determination to master their futures.

We do not yet have conclusive outcome data. Nor do we know exactly how the program will affect girls as they grow into young women. We suspect they will be less intimidated by machines, computers, tools, and science equipment, and as a result, more likely to keep all their options open as they consider future education and careers.

What we do have are stories and observations of how girls and the women who work with them behave in the context of Operation SMART. What we also have are ideas of what approaches are most likely to produce the kind of change in attitude and action that we are looking for.

Early on in the project we realized that simply providing girls with access to science experiences and computers was not enough. Real and perceived barriers to participation in math, science, and technology stop many girls and women before they even try. They are bombarded with messages, many of them negative, that say "it's not for girls." To engage in science and technology, we had to delve into the relationship between gender stereotyping and scientific pursuit.

We then thought about the qualities of a scientist -- persistence, invention, creativity, risk-taking, self-direction, singular pursuit of an idea, willingness to fail and learn from mistakes, continual questioning. We considered how social expectations for girls and women -- to get the answer right, be obedient and polite, listen to directions, place others' needs and interests first -- inhibit those qualities. We theorized that the mandate to be neat and clean and ladylike prevents initial engagement with science and the physical world. It was this thinking that led to our slogans: Create, Discover, Take Risks, Get Messy; and to our underlying approach of scientific inquiry, in which we encourage girls to be skeptics, not take anything for granted, and to generate for themselves the questions that are of burning interest, the questions that don't go away.

Research confirms that girls and women have not had the same degree of experience with science equipment and computers as their male counterparts (Sanders and Stone, 1986; Hueftle et al, 1983). We extrapolated from these findings to recommend that girls in Operation SMART use all kinds of tools and technology, not just microscopes, bunsen burners, and test tubes.

The act of engaging in these non-traditional pursuits appears to have a powerful impact on the way girls and women think about themselves and how they approach other aspects of their lives. Although we do not have long term data, we expect that competence once learned is not easily forgotten.

As Girls Clubs across the country implement Operation SMART, a number of themes have emerged that shed light on girls' and women's relationship to technology:

Demystification

When girls understand the logic and workings of a machine or a tool, they are more likely to use and master it.

> At a Girls Club in Massachusetts, the new Apple computer caused a variety of reactions among the girls. A few went right up to it and started playing; others hung back and watched; still others feigned indifference, doing other activities in the same room, their eyes continually darting over to the computer area. Then the adult leader brought in an old broken Commodore and a set of tools. "Take it apart," she suggested. All the girls joined in, examining each piece in turn, categorizing and sorting, and approaching the task systematically. Then they turned back to the Apple: no more fear or resistance. The machine was theirs.

Girls in Operation SMART are encouraged to take it apart -- whether "it" is an appliance, a computer, a word problem, or a decision about enrolling in math and science courses in high school. The physical dismantling helps provide the conceptual framework for thinking about the whole and its component parts. While younger girls may not be cognitively ready to make this connection between the concrete and the abstract, they are likely to retain both the phrase -- "take it apart" -- and the method. Certainly for early adolescents, teen women, and adults, the analogy is an effective one.

Hands on

The actual manipulation of the materials and tools is an essential aspect of the experience:

> The planned activity was one in which girls were to experiment with hammers and leverage. They were supposed to try hammering a nail into a piece of wood holding it first by the head, then by the middle, and then by the base; they were to record how many strikes it took to hammer the nail in each way. The girls looked at the directions, looked at the nails, and then began hammering away with vigor and enthusiasm, ignoring the recommended test. They quickly figured out which grasp worked best. They hammered everything in sight. When they ran out of wood, they split the pieces, using a variety of strategies for breaking the planks. When they ran out of nails, they pulled out the ones they had already hammered and straightened them back out. For two hours, they kept at it. No one used the tools inappropriately, no one got hurt; the noise

level was pretty high, but other girls in the room were not distracted from what they were doing, nor were the hammering girls distracted from their pursuit. It was not the experience the adults had expected them to have, but they certainly learned a great deal about leverage, force, resistance, striking with accuracy, and impact, as well as about the materials of iron and wood.

In a science experiment demonstrating erosion (smash a brick in a bag, put the shards in a can of water, swing the can a thousand times, and examine the pieces again), we have noticed that it is the act of pounding with a hammer that is the most compelling part of the experience for the girls. They revel in the force and the control they discover they have over what appeared at first to be an invulnerable object.

Getting hands on is critical, but it is not enough. Reflection -- articulating reactions and sharing those feelings verbally or in writing -- helps girls to internalize the experience, make connections to other situations in their lives, and retain what they have learned both about the science and about themselves.

The symbolic is important

To work with big materials and power tools gives girls a message that they themselves can be big and powerful. Many perfectly wonderful building activities use straws and toothpicks, teaching valuable principles about structure and stress. But girls are traditionally "good" with the small things that require fine motor skills, and they are most often offered materials that lend themselves to precision rather than force or leverage. So whenever possible, we recommend using big materials (dowels, planks, big wooden blocks, and bricks) and teaching safe use of power tools so girls learn to take reasonable risks and get a feeling for heavy machinery and motors.

The simplest tool can be the medium

Girls' hands turned out to be the best tool for exploring oobleck, a mixture of cornstarch and water that defies categorization:

> Girls used their fingertips, palms, and nails. They poked, squeezed, pulled, and let it run between their fingers. "What is it? What is it?" they kept asking. With eye droppers they added water, then poked at it some more. "It's not a liquid and it's not a solid," exclaimed a ten-year-old. "It gets harder, not wetter when you add just a little water," observed another. They added lots more water and immersed their whole hands and forearms. They spread it out on the table. Then they watched what happened when the oobleck dried. "Ooh, now it's solid again. I can just brush it off with my fingers."

Nothing came between the girls and the substance, and it was their fingers and skin that allowed them to discover oobleck's properties, to observe with their touch, and to question how their assumptions about matter were thrown into confusion by this strange stuff.

The most commonplace instrument can be a tool or machine. As Sprung, Froschl, and Campbell point out in their book about young children and the scientific method, we are surrounded by machines but often don't recognize them as such. The light switch, water faucet, and tape dispenser all qualify, but desks and chairs don't, since they "don't do anything. Doorknobs are machines because they transmit the motion of turning the knob into moving the latch so the door can be opened." (1985, p. 94).

Time to learn, room to explore

Schools give the message that learning should happen in a prescribed period of time. Math is often presented as a competition against the clock: faster is better, slower is not good enough. When patience and respect for the process replace the deadline approach, girls can take a new view of science and technology.

> A nine-year old girl looking at sand specimens through a plastic microscope was moving so quickly and nervously that she was spilling sand all over the place. She knocked the lens out of the microscope and exclaimed, horrified, "I broke it; I'm gonna get killed." The leader assured her that she hadn't broken it, that no one was going to get angry, and that she could have as much time as she needed to use the microscope. The girl calmed down and proceeded to view each type of sand systematically.
>
> Building with four foot dowels and rubber bands, an eleven-year-old girl was being assisted by an adult SMART leader. The girl made a cube with the poles, which kept collapsing. Rather than making suggestions, the leader asked the girl what she thought might make it more stable. The girl decided to support it by propping dowels against the structure from the outside. She was starting to discover the strength of triangles when it was time to leave. The leader told the girl "we'll leave this up for you if you want to work on it some more tomorrow," and she told her colleagues, "give her one more day and I'll bet she'll figure out that if she adds diagonals inside the cube she'll get the stability without the props."

The way the room is set up can make a big difference. Tools within reach, machines to dismantle on the shelves, gears to play with on the tables, computers accessible (we have a wonderful series of photographs of teen women from the Springfield Girls' Club Family Center laughing and working together on the Apple IIc that is set up on the floor) say to girls, "technology is for you." So too with posters that show white women, women of color, and women with physical challenges in non-traditional jobs, actively engaged with science and technology. "Let the walls speak," says the Operation SMART manual.

Good science demands collaboration and sharing expertise

"I cheated," confessed Harriet, as she described how she had made the bulb light only after she had watched the woman sitting next to her figure out

where to connect the wire to the battery. Schools also teach us that it doesn't count if you didn't do it all by yourself; even in classrooms where team efforts are encouraged, students are still graded on their individual effort. Yet, at work and in the family, problems and decisions are far more often solved by a group of people working together.

SMART leaders and girls learn there are many ways to approach a problem, some more effective than others, but all legitimate starting points. With batteries and bulbs, we have observed that some people seem able to figure out what to do by handling all the materials and then messing about with them. Others play a little and then get stuck; still others need help in the initial step and then can take it from there. In reflecting on the process, participants come to grips with their own strategies and styles:

> "I need to get my hands on the stuff first. When I can feel things, then they start to make sense."
>
> "I want an intellectual overview of what's going on here. Remind me about circuits and circles -- give me the framework -- and then I can tackle it."
>
> "I can come up with the idea by myself, but then I don't know where to go with it. If I watch someone else, I get over the hump."
>
> "It was much easier when I worked with someone else. She had ideas when I didn't, and I had ideas when she didn't."

Crediting alternative approaches to science and thinking

Too often, girls think that their way of doing things is somehow less valid or effective than the boys' way.

> Twelve-year-old Tracy drew a rocket. Her boyfriend, sitting next to her, then drew an almost identical rocket. Tracy crumpled hers up, saying, "Yours is great. Mine's no good."

Turning difference to advantage, an eight-year-old girl commented to her mother, "The boys are better at being destructive, but we are better at being creative," following an experience that the SMART leader described as follows:

> Last June, we received a donation from a bank of 12 old adding machines -- the kind with 100 buttons, whole rows of 7's and 8's. Functional but obsolete. So we bought several packs of screwdrivers and turned the kids loose. We told them to take the machines apart, see how they worked, and save the parts. The girls decided to build a robot with the parts. After the first day, they lost interest in the demolition part of the project. The boys kept at it: they got every last machine apart down to the tiniest spring. The girls just kept checking on the boys' progress and claiming the discarded parts. The boys didn't seem interested in keeping anything but the little motors they found ine ach machine. Meanwhile, the girls were drawing plans for the robots, using

the part from the machines. They ended up wtih eight buckets of gears, buttons, levers, springs, and screws, and some very interesting structures -- maybe not quite robots -- with moveable parts.

The recent literature (e.g., Keller, 1985) that challenges male conceptions of science provides a conceptual and research base that can articulate for SMART girls and women that science is not immutable but defined by social and political forces, the same forces that have created a situation of inequity in access to science education and careers.

Confronting learned incompetence

Many girls and women have been told, sometimes in words and sometimes in other ways, that they are simply not capable in the realm of tools, equipment, and technology. Self-fulfilling prophecies -- "I'm gonna break it," "I can't do it" -- need to be challenged to be overcome. The support of the group, the knowledge that the problem is not yours alone, and the sharing of stories can make all the difference:

> An adult member of the national staff recalled how her father, an otherwise enlightened and supportive male, had always called her mother a "mechanical moron," and at some point began telling Caren she was just like her mother in this regard. "I never did anything mechanical; if something needed to be fixed, I'd wait until my father or brothers came home. Yet I still thought of myself as a feminist, someone who is able to do things for herself." Operation SMART made Caren question both the familial label and her reactions to it. One day she came into the office and reported that she had taken apart and reassembled her dresser to fix a wobbly leg. Some weeks later she put up shelves, and then laid a kitchen floor. Now she is collecting parts for a stereo that she is building herself.

Self-reliance

Using tools liberates girls from dependence on males to fix it for them. The bike repair story from Schenectady is a positive example; often, however, girls assume they can't and boys can, as this story from the Holyoke Girls Club reveals:

> The SMART Coordinator had set out batteries, bulbs, wires, and switches. The girls approached the table, but didn't touch anything. "Go ahead," urged the Coordinator. "See what you can do." Nine-year-old Annabelle asked her, "Can I have a dime, Elyse, so I can call my brother? He knows how to do this." Instead of giving her the dime, Elyse offered encouragement and thought-provoking questions. Annabelle completed the circuit and made the bulb light. "I can do this myself!," she realized.

Once shown the possibilities, many a girl and woman will adopt a new attitude:

> At a workshop for staff where we had asked people to bring in broken appliances, Jenny became engrossed in fixing the lamp she had brought

from home. She was so adept with the screw driver and so purposeful about how she approached the rewiring that we were sure she had done this many times before and worried that she wasn't getting anything new out of the activity. "Oh, no," said Jenny, "I've never tried this in my life. My husband does everything like this, and he never lets me near the tools. That won't ever happen again."

Two steps forward, one step back

Even as some barriers are overcome, others prevail. From the Syracuse Girls Club comes this tale of mixed messages, sex role stereotyping, and family influence:

> Girls and boys were taking appliances apart. Marian was very interested in participating, but her brother kept saying, "I don't want her to do this. She might get hurt!" The other boys seized hammers and immediately started banging away on the appliances of their choosing -- adding machines, toasters, old stereos. Finally, Marian decided not to listen to her brother and carefully started disassembling the appliance that appealed to her. She tried different screw drivers until she found the one that worked the most effectively, and asked questions why it tightened the screw one way and loosened it the other. And she was delighted when she finally got all the pieces arranged and was able to make some guesses about how the pink Barbie radio worked.

Girls and women's visions of their own competence have an impact on others

The boys in the Schenectady backyard, the brother in Syracuse, the fort builders in Casper were all forced to take a new look at their female peers, to reevaluate existing relationships, and perhaps to discover alternatives to a sexist, stereotyping society. The Operation SMART manual advises Clubs to show girls in action doing math, science, and technology as a way to raise expectations among adults and young people of what girls can do, and to break down preconceived notions of limits and prescribed roles.

Operation SMART seems to have an effect even in the office of the national organization, as a male member of the staff writes:

> "I wonder how Operation SMART has changed my views, a man's views, of women's competence. Do I no longer asssume 'a woman can't do it?' Am I more willing to allow a woman a chance to solve a mathematical, scientific, or technological problem? Are my expectations of a woman's performance higher? Working in GCA's feminist environment, it's hard for me to know how much this change in my attitude comes from myself, the agency's beliefs, and Operation SMART's goals. All I know is Operation SMART carries a strong message."

Girls' and women's visions of their own competence have an impact on themselves

Ultimately, our aim is to help girls grow into self-sufficient, responsible, and self-fulfilled adults. Both the women and the girls Operation SMART has

touched comment on how the immediate result of their tackling technology has been to build confidence and to make them feel that they can do all manner of things, not just use tools and operate a computer. In the words of twelve-year-old Jamaica as she takes oil can to bike:

> It looked complicated. Cause it was all greasy and ucky and dirty. At first, I didn't want to. But then, dirt ain't that bad after all. So it's kind of fun after awhile, when you, like, fix the wheel, and you feel good about yourself -- because you know that <u>you</u> can fix it.

No one can tell Jamaica to feel that way; she must come to it herself. The best we can do is to create the opportunities and environment to promote these kinds of realizations, and to ground the program and activities we recommend in research and real experience.

Thus these stories and themes are only a beginning. They suggest dozens of questions to pursue. Most immediately, we need to know whether there is a lasting effect. We also need to know how these stories fit into the scholarly literature about cognition, human development, and the history and anthropology of women's roles. And finally, we need to know more about how using tools causes, responds to, and perpetuates a change in the social order.

Engendering a sense of power and belief in oneself is central to the goals of Operation SMART. So too is building a new view of science, one that represents more fully the right and necessity of participation by all people -- women and men, minority and majority, those with challenges and those without. The evolution of the human species is in part dependent on our tool making and tool bearing capacity; our continued survival is dependent on a population that construes technology as a constructive, not destructive, force. In Operation SMART, we are trying to give girls their birthright as human beings, offering them the tools -- both physical and intellectual -- to take control of their lives and to make decisions that have a positive impact on the world in which they live.

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